Design and Construction of a TPC with GEM Readout

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ECFA Study – Physics and Detectors for a Linear Collider

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ECFA Study
Physics and Detectors
for a Linear Collider

bmb+f
Großgeräte
der physikalischen
Grundlagenforschung

Overview

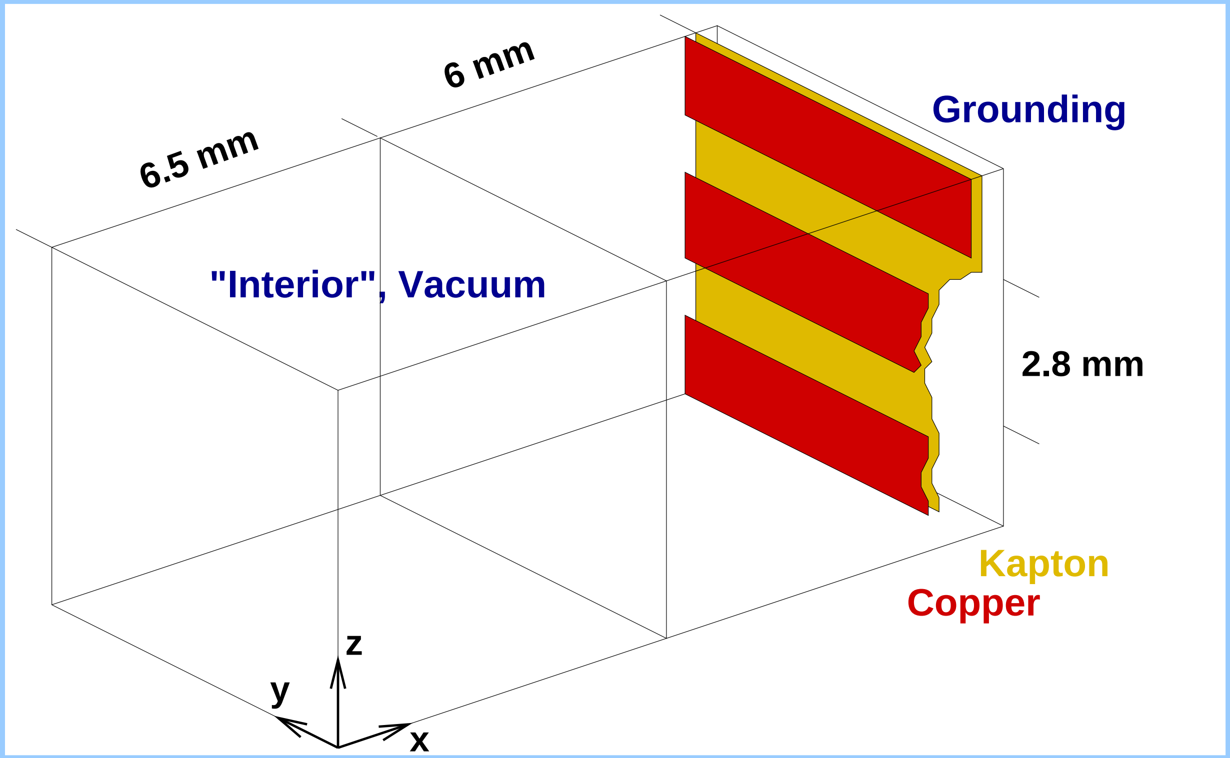
- Development of a TPC prototype
  - Optimisation of the fieldcage
  - Construction and first measurements
  - Readout electronics
- TPC simulation

TPC Prototype: Requirements

- 5T magnet at DESY: 280 mm bore
- SMD resistors as voltage divider
  $\Rightarrow$ minimal pitch = 2.8 mm
- Materials with low density
  (radiation length)
- GEM readout from test TPC
  should be used
- 26 kV for drift field available

TPC Prototype: Simulation

- Optimisation of the field cage
- Simulations of strip geometry with Maxwell 3D:
  copper strips on one or both sides,
  different ratios of strip width and distance with fixed pitch (2.8 mm)



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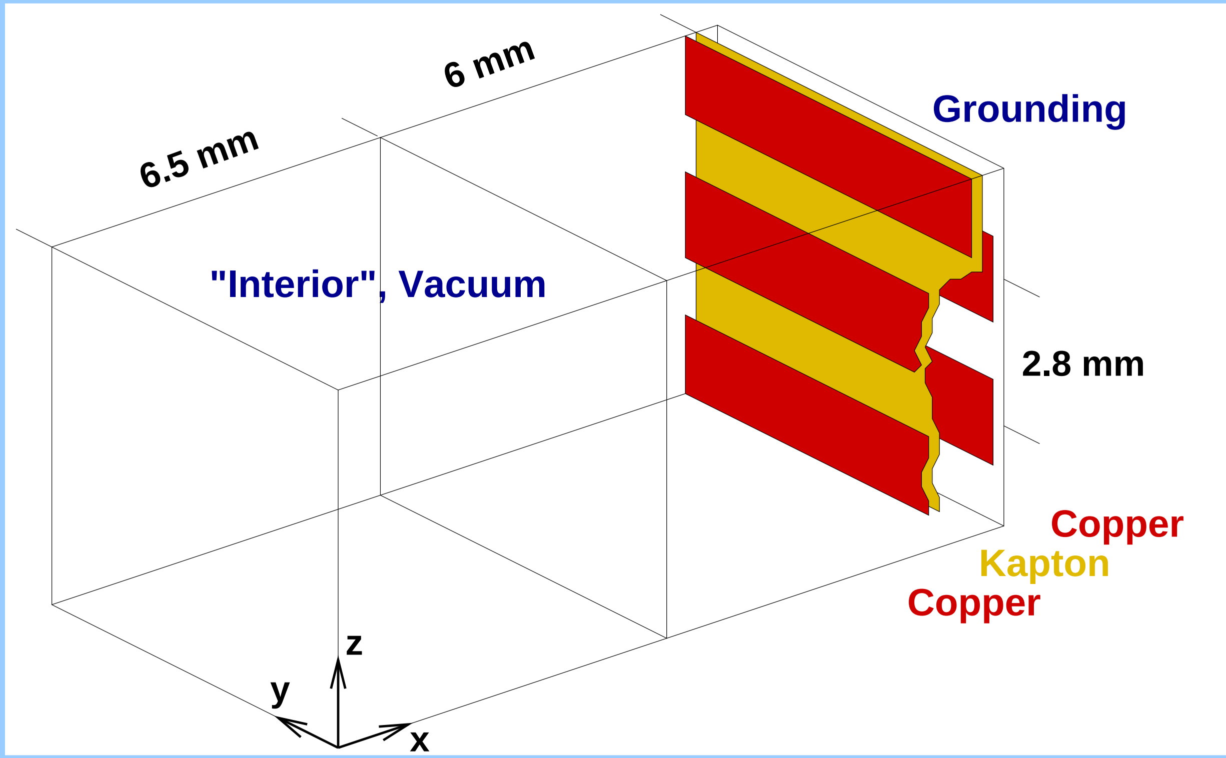
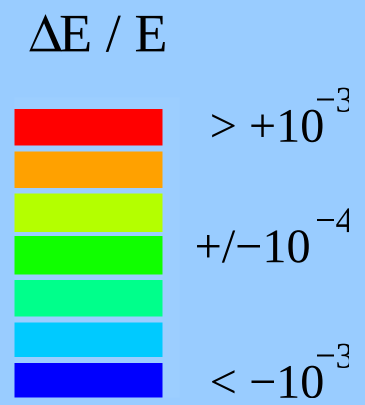
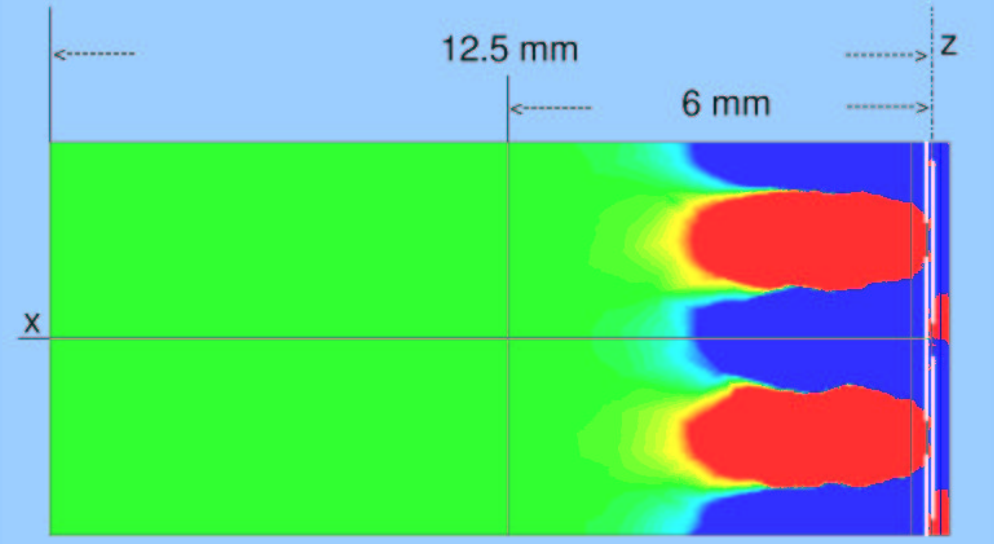


TPC Prototype: Results of the Simulation

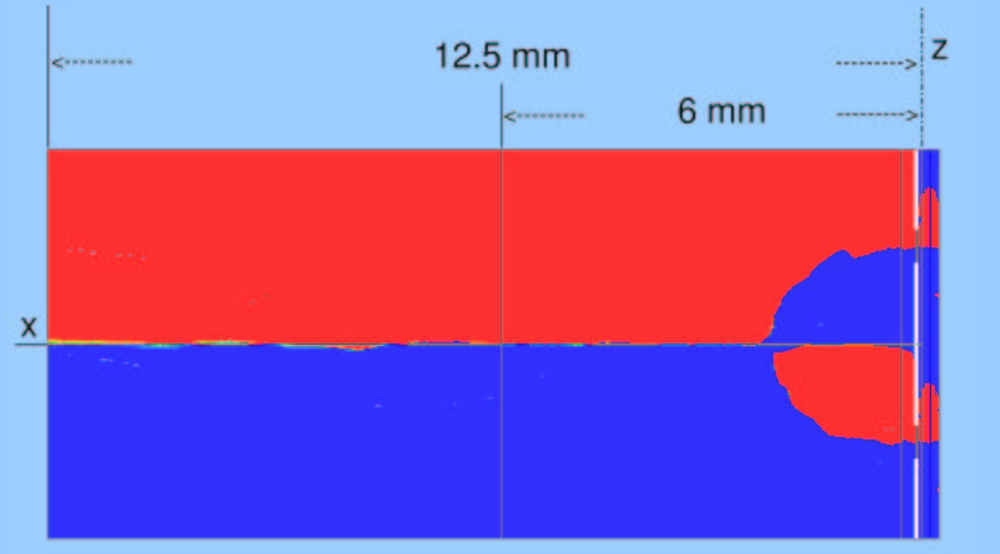




$E_{parallel}$, strips on both sides

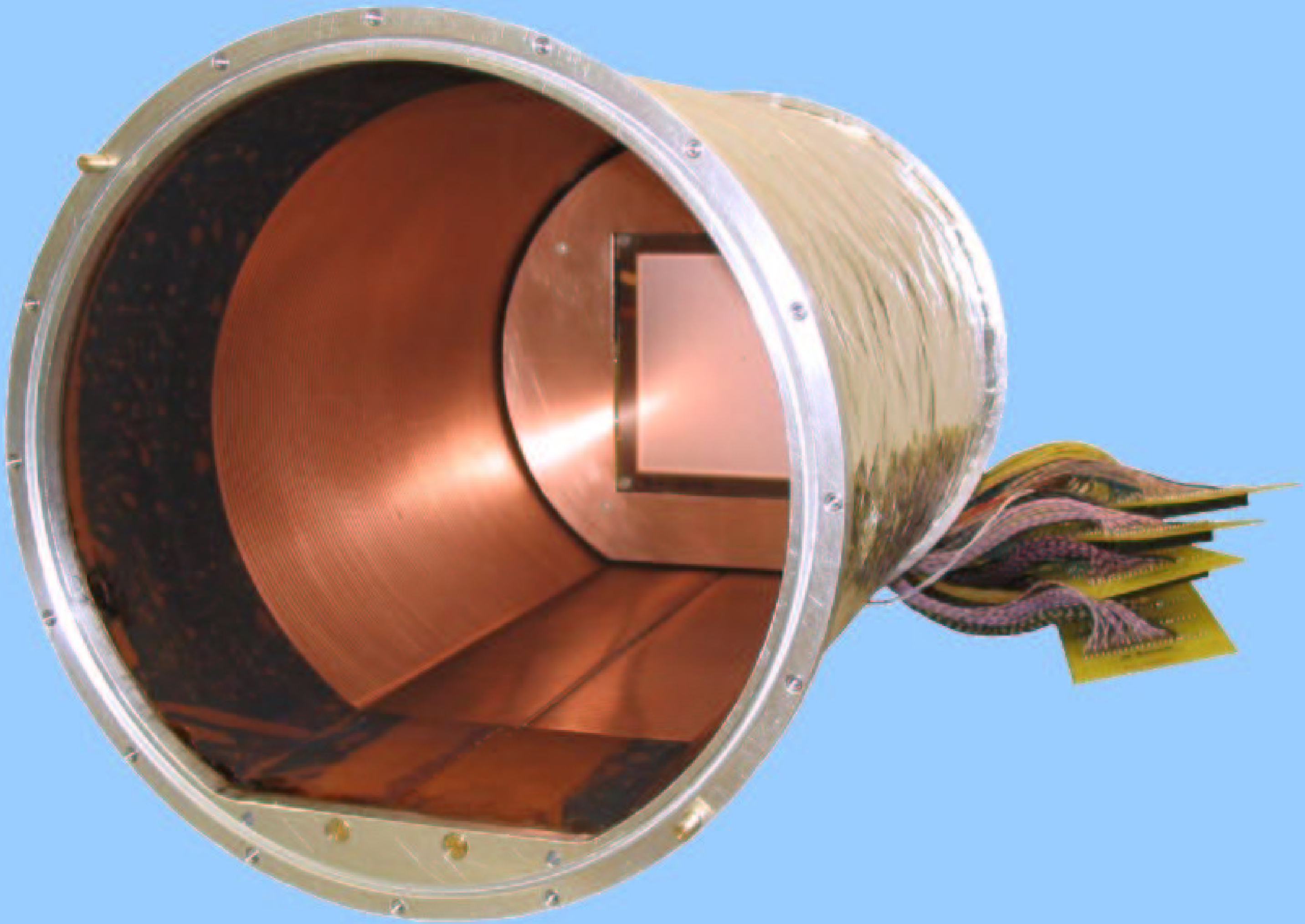
Copper strips:
width 2.3 mm
distance 0.5 mm

$\Rightarrow$ field with double-sided strips much better than with one-sided strips



$E_{parallel}$, strips on one side

TPC Prototype: Construction



Ø = 260 mm

pitch = 2.8 mm

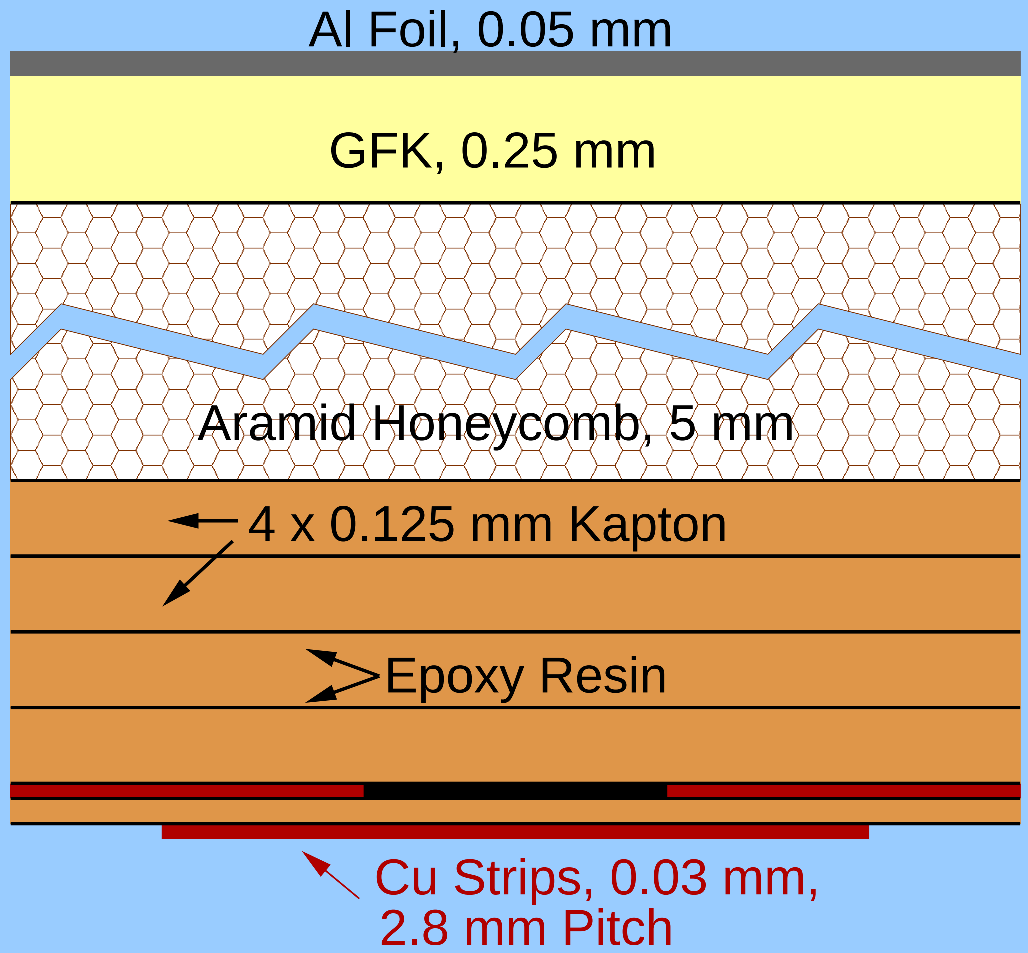
R = 4.7 MΩ (SMD)

U_{max} = 26 kV

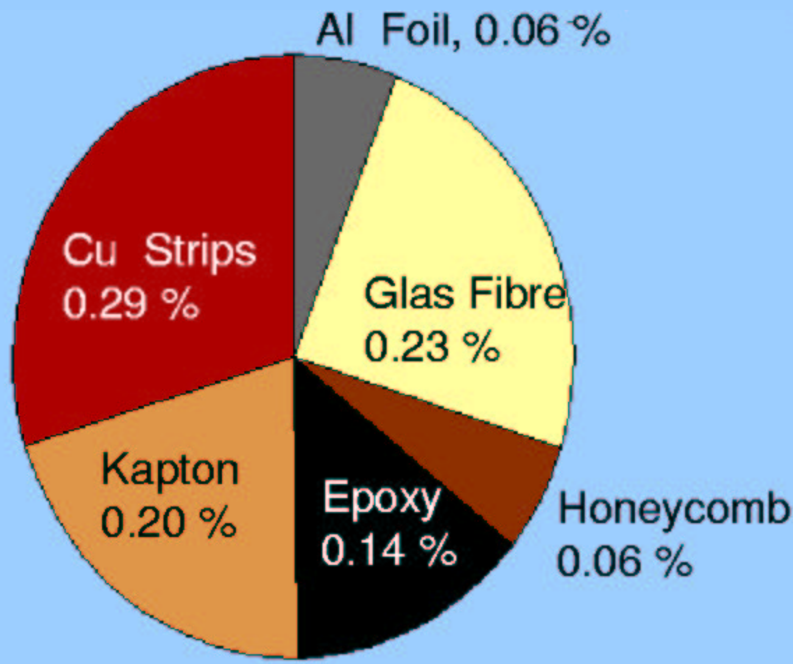
ℓ_{drift} = 26 cm

E_{max} = 1000 V/cm

TPC Prototype: Radiation Length



fraction of radiation length

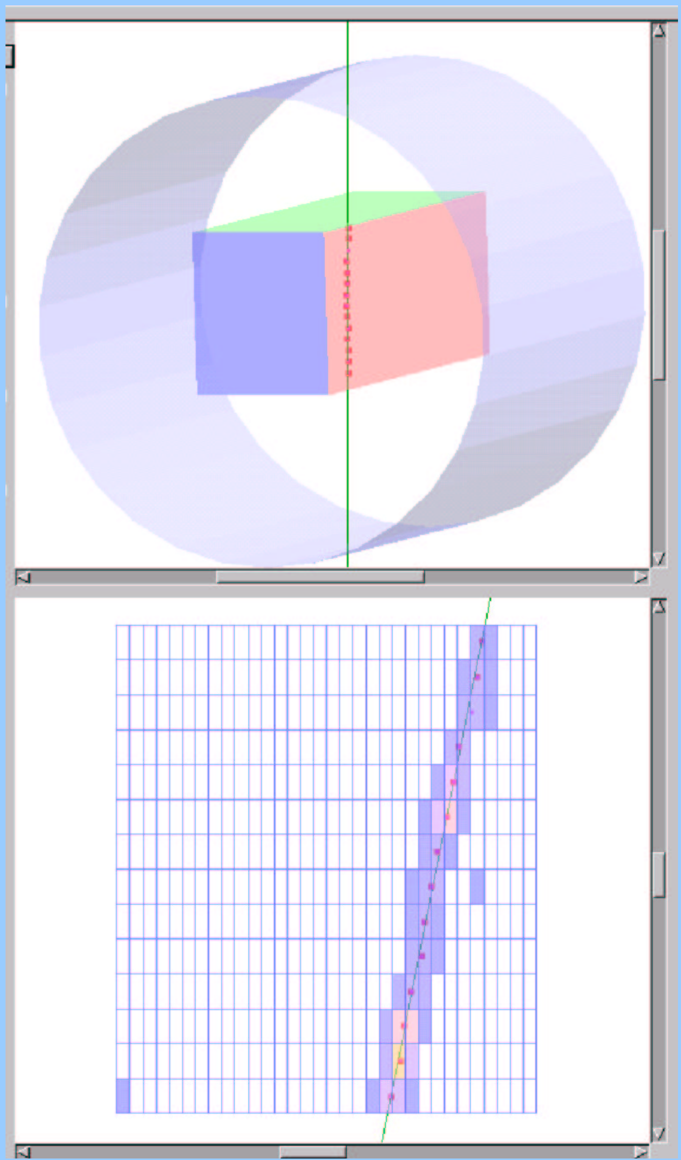


altogether 1% radiation length

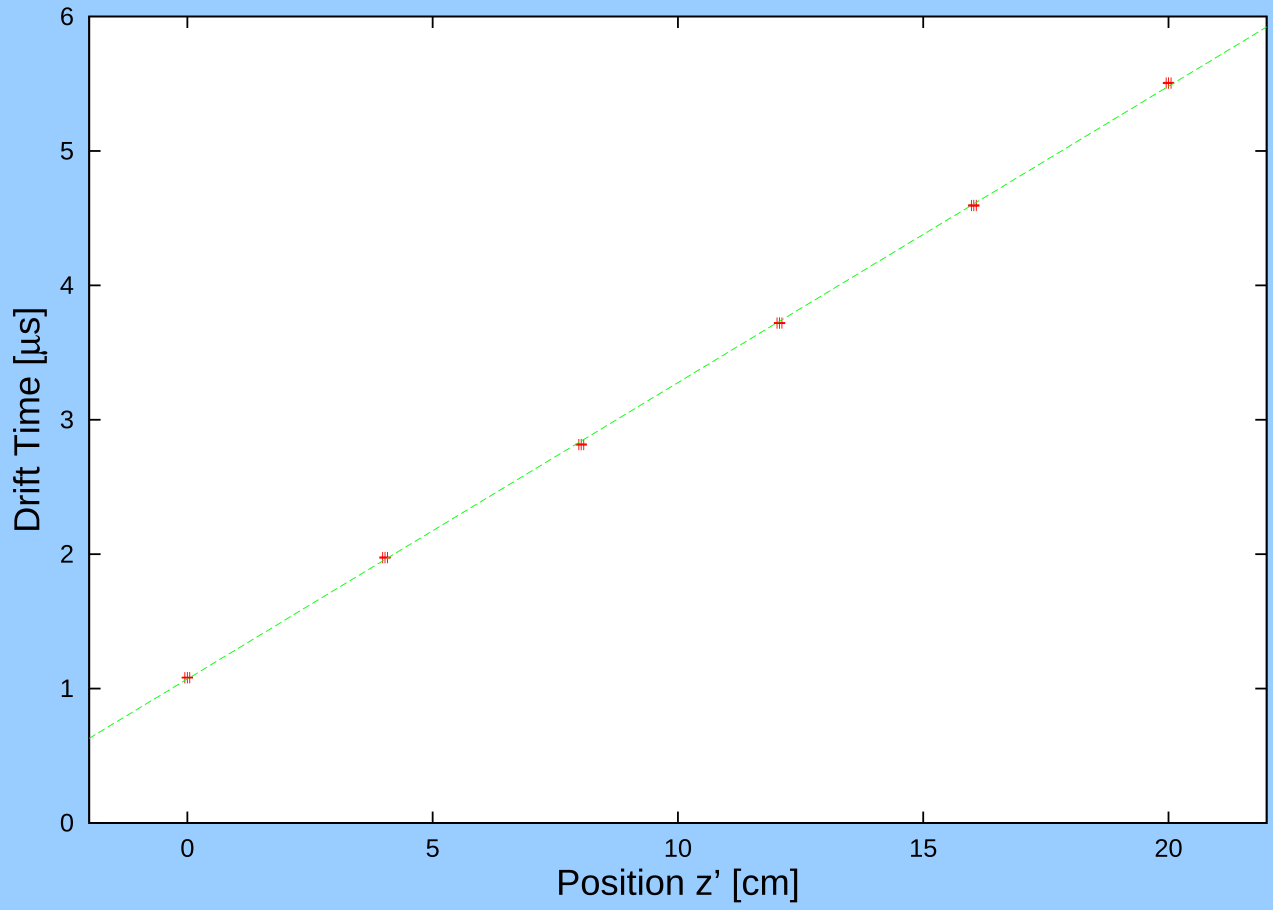
$\Rightarrow$ 3 % radiation length possible (TESLA)

TPC Prototype: First Results

First event



Homogeneous drift velocity



TPC Prototype: Readout Electronics

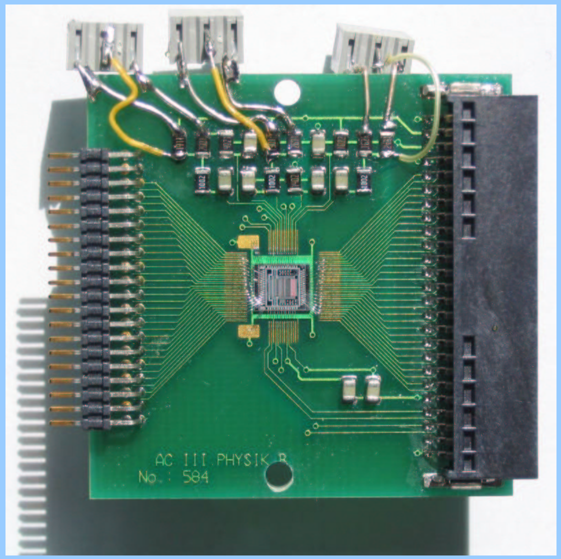
Goal: Develop a test readout with 512 channels for our TPC

Requirements:

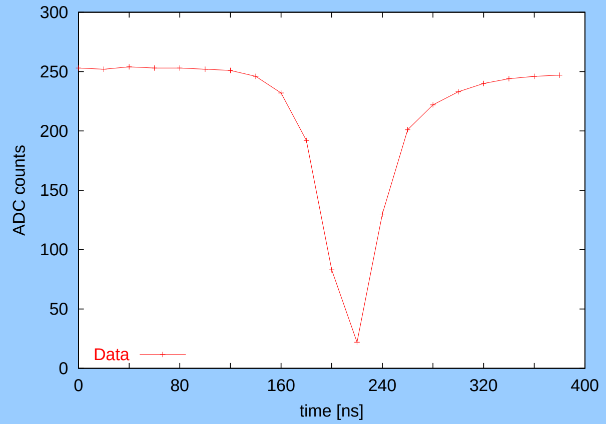
- fast preamplifiers to study time resolution
- small preamplifiers to allow compact readout design with small pads
- fast ADCs to match the preamplifier speed
- fast data aquisition to allow reasonable operation in test beam runs

Current Status:

- first signals with preamplifiers
- no full ADC instrumentation yet



Preamplifier



Test chamber pulse

TPC Simulation: Motivation

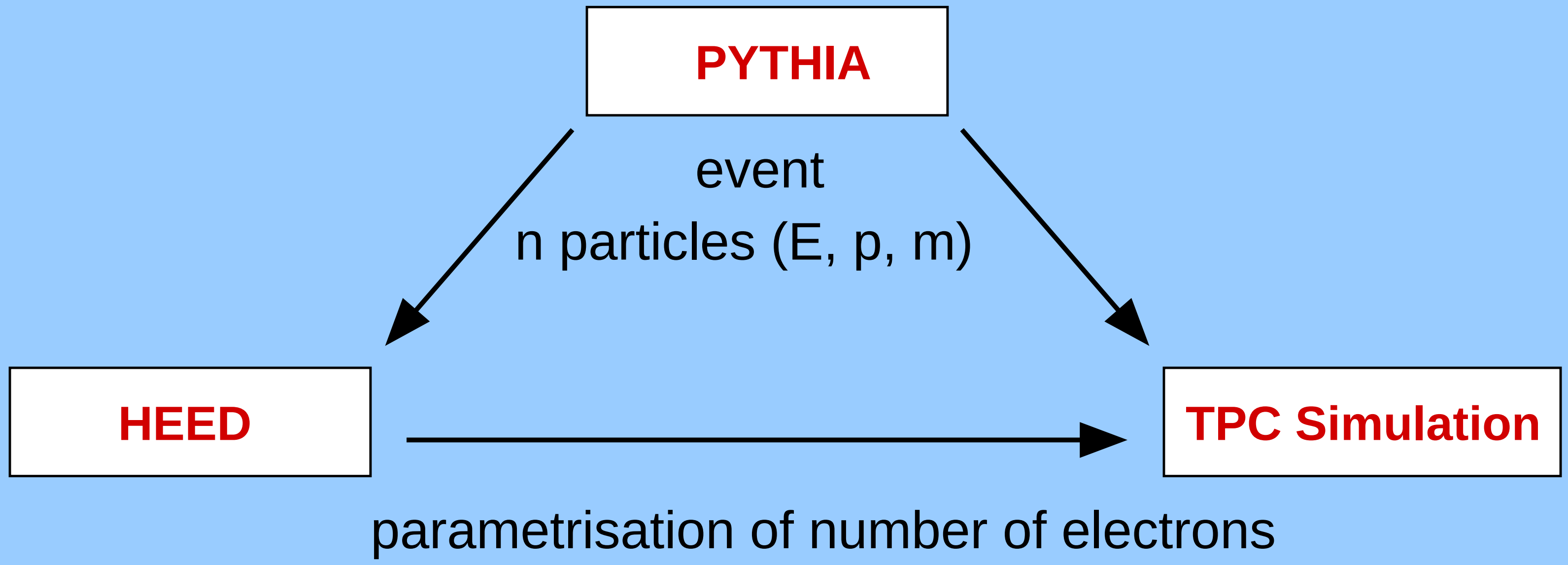
MOKKA / GEANT $\Rightarrow$ simulation of the whole detector

Our Goal: simple and efficient tool to simulate a TPC

$\Rightarrow$ analysis of the specific properties of a TPC, e. g.

- properties of electric and magnetic fields
- production and transfer of electric charges
- amplification in GEM structures
- ion backdrift
- pad response

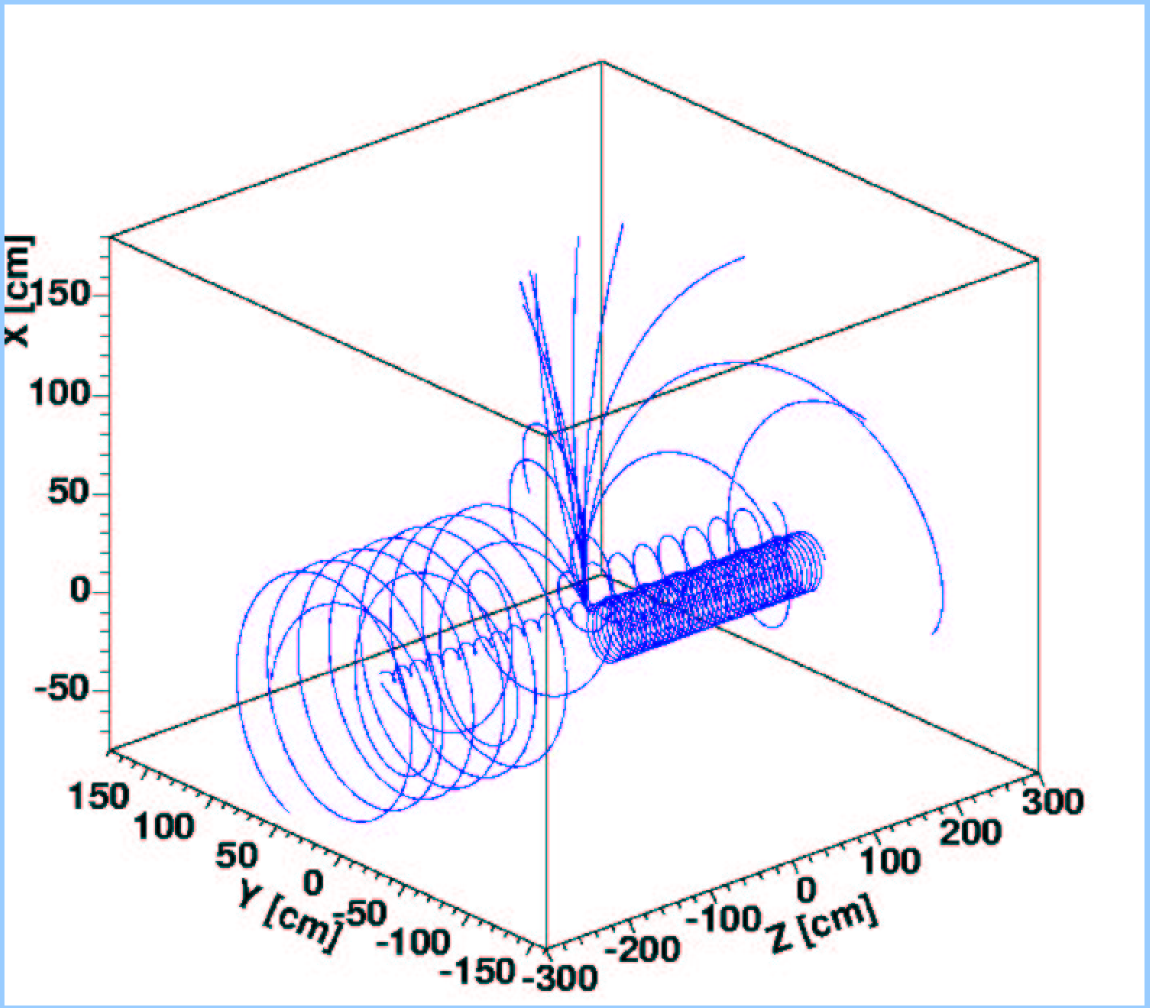
TPC Simulation: Approach

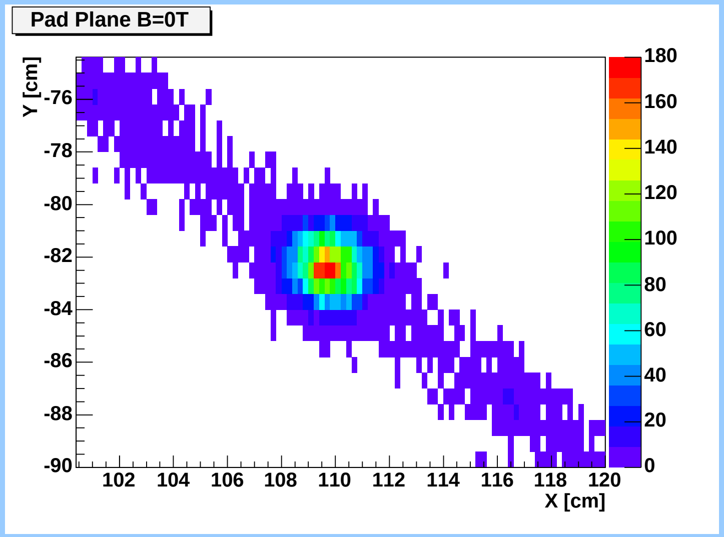


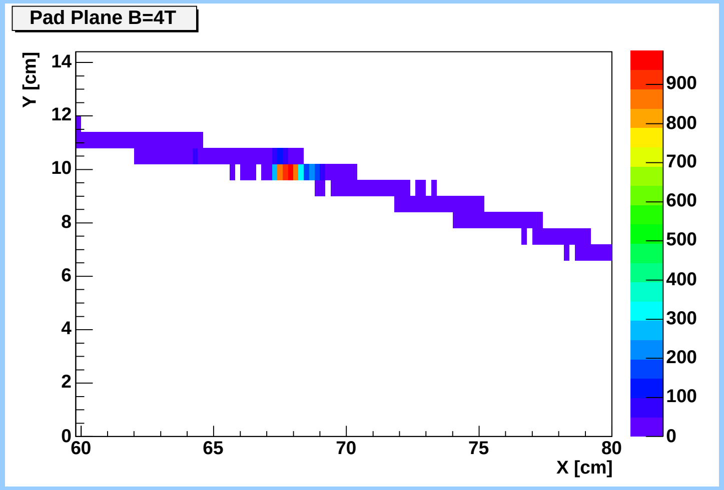
- number of electrons along straight line
- clustering
- delta electrons
- without B field
- no 3D information

- dice number of electrons (Landau distribution)
- small track units −> approximation of clustering
- no delta electrons
- with B field
- 3D information

TPC Simulation: Status







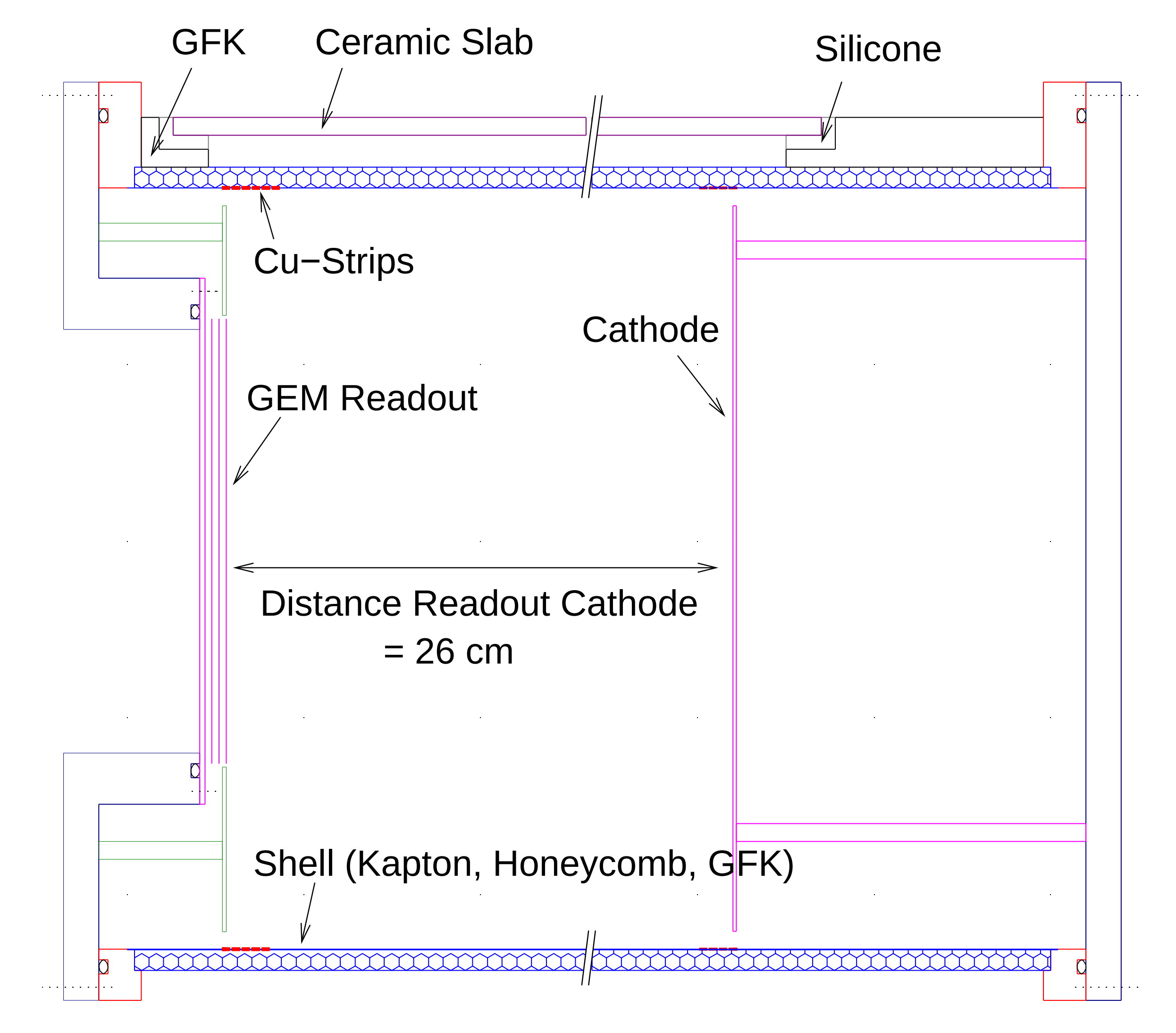
simulated event, 3D view

pad size $2 \times 6\,\mathrm{mm}^2$

Conclusion

- TPC prototype for use in magnet constructed
- First cosmic muons observed, homogenous drift velocity
- Development of new readout electronics for use in test beams ongoing
- Basic simulations of 3D event in TPC

Backup TPC Construction



xz profile of the TPC prototype

Ø = 260 mm

pitch = 2.8 mm

R = 4.7 MΩ (SMD)

U_{max} = 26 kV

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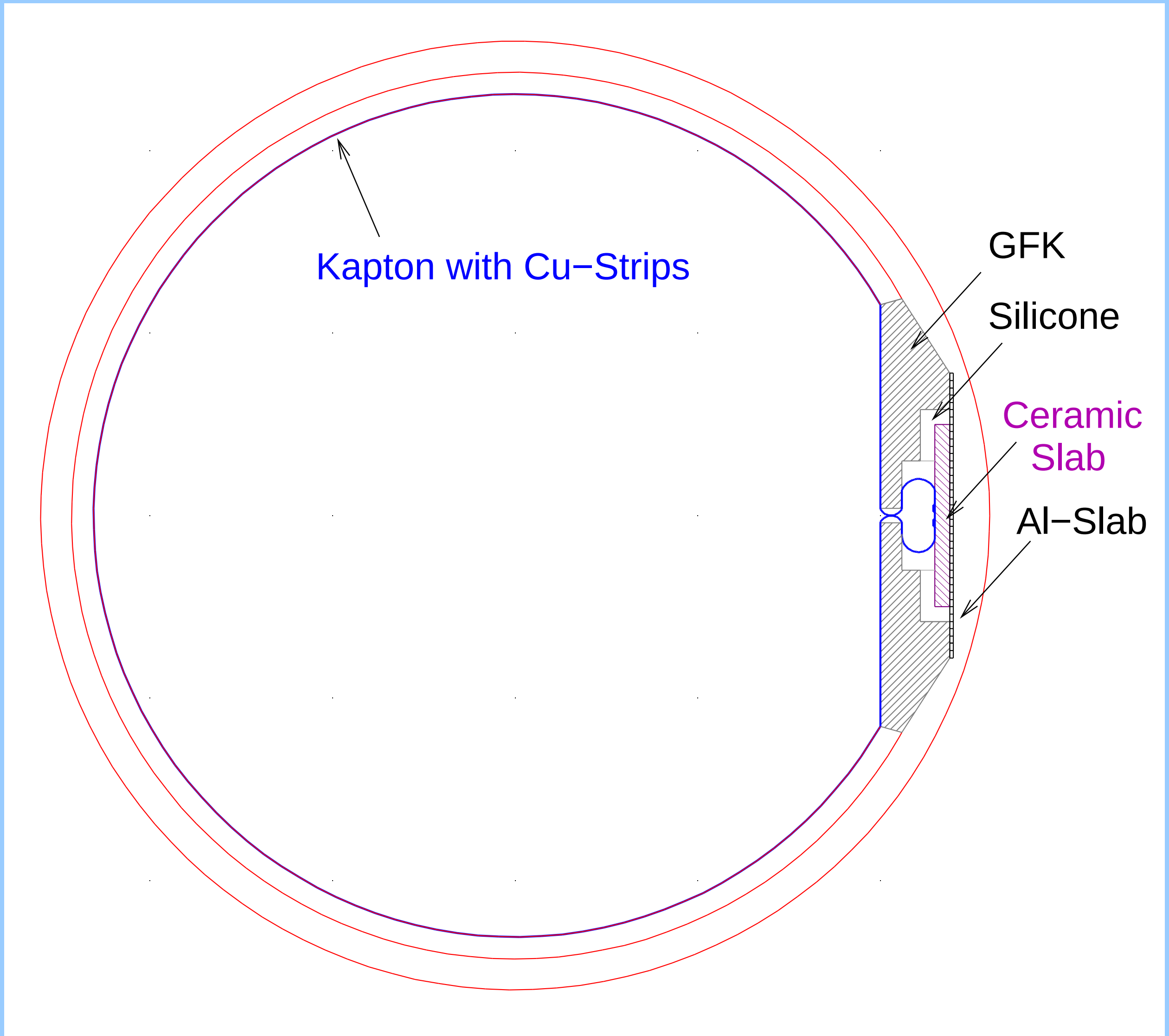
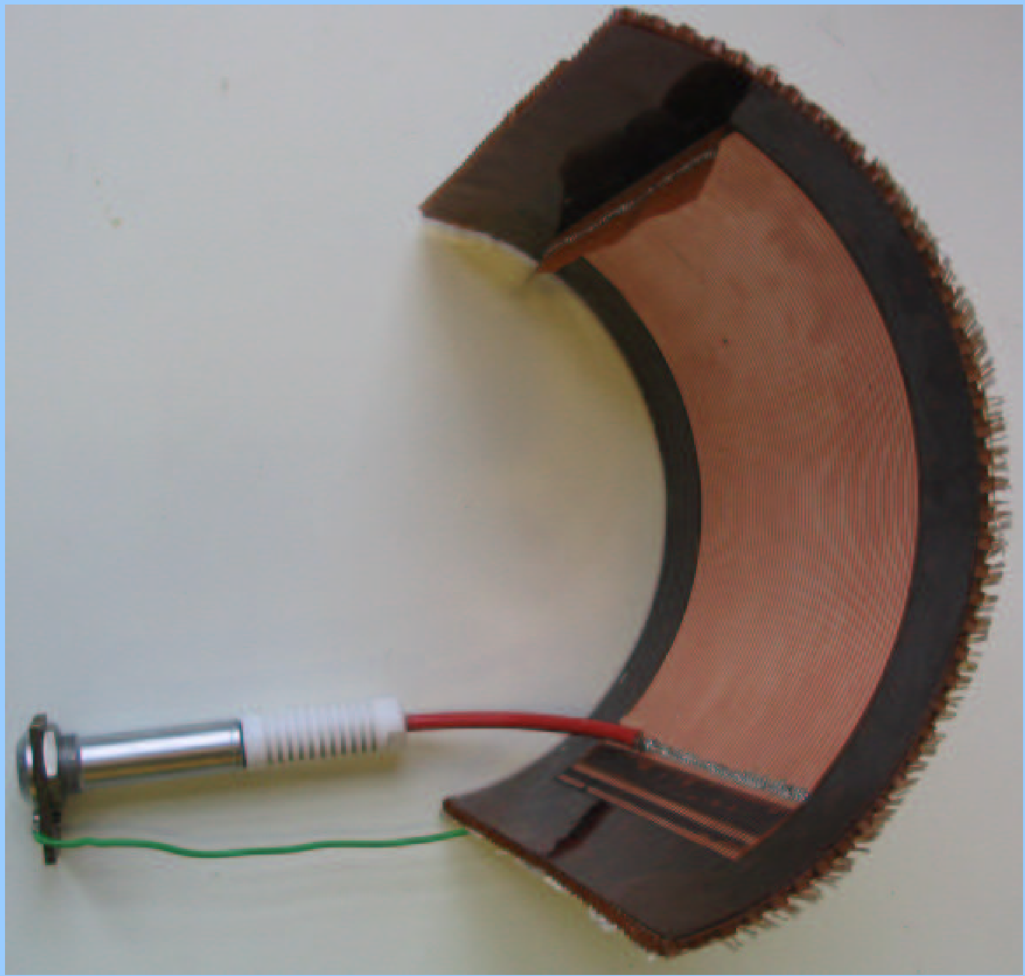
E_{max} = 1000 V/cm

Backup: TPC Fieldcage



xy profile of the field cage

Backup: HV Tests for the TPC Prototype



test of dielectric strength of the sandwich structure:

$U = 30\ \mathrm{kV}$ one week without trip

final strip design: inside: width 2.0 mm, distance 0.8 mm

outside: width 1.8 mm, distance 1.0 mm

Backup: ADCs

criteria	requirements	status
bus type	VME	VME
resolution	$\geq$ 10 bit	8 bit
sampling rate	$\geq$ 40 MHz	50 MHz
channels per module	$\geq$ 16	4
channels total	512	20

$\Rightarrow$ no solution yet!

But 32 channel ADC from TU Munich (Igor Konorov) is tested!

- Tracks
  1. read PHYTHIA event $\Rightarrow E$, $\vec{p}$, m
  2. for each particle: dice number n of electrons per cm (Landau distribution)
  3. dice coordinates of electrons on each part of the track along $\vec{p}$ (uniformly distributed)
  4. calculate energy $E' = E - n \cdot 26\,\mathrm{eV}$
  5. repeat steps 2-4 until particle has left the TPC or $E' = m$
- Drift
  1. parametrisation of gas properties $\Rightarrow v_{\mathrm{D}}(\vec{E}), d_{\mathrm{l}}(\vec{E}), d_{\mathrm{t}}(\vec{E}, \vec{B})$
  2. dice according to the parameters (Gaussian distribution)